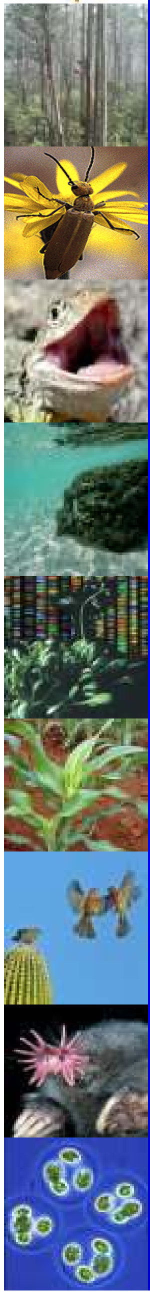
Taking Stock of Where We Are: NSF/BIO Update

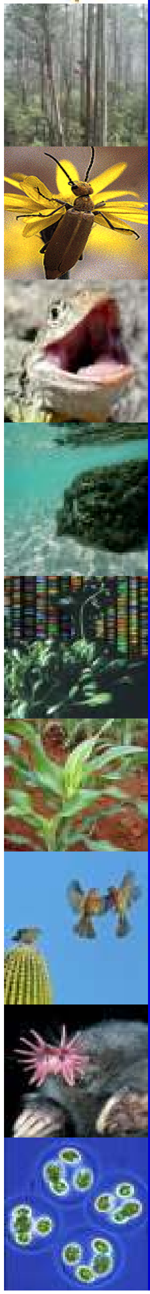
Advisory Committee for Biological Sciences Fall Meeting

James P. Collins, NSF Assistant Director for Biological Sciences
National Science Foundation
10 September 2009



Outline

- The Changing Science and Technology Environment
- NSF Budget and Activities
- Fostering Innovation
- Promoting a Tipping Point in Academia



Shifting Science Priorities

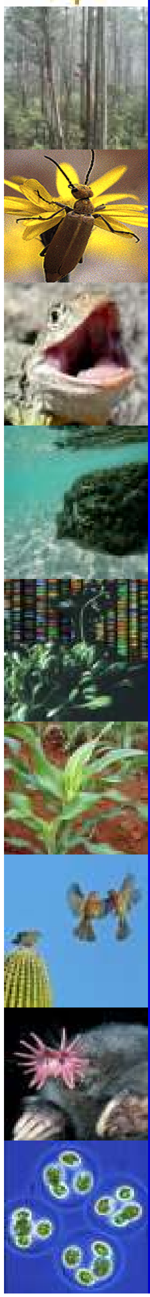
Energy & Environment

Barack H. Obama

John P. Holden

"Of all the challenges we face as a nation and as a planet, none is as pressing as the three-pronged challenge of climate change, sustainable development and the need to foster new and cleaner sources of energy."

Office of Science Technology and Policy

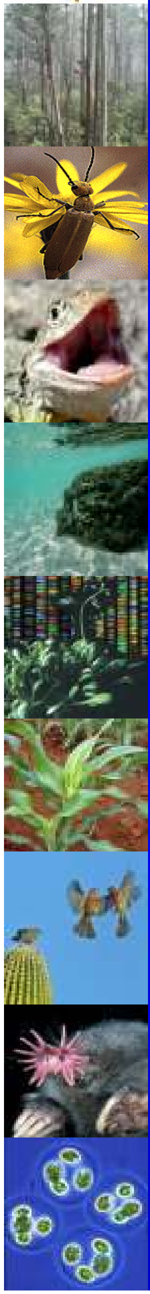


America COMPETES Act

- Signed into law on August 9, 2007
  - Authorizes doubling of NSF Funding from \$5.6 billion in FY2006 to \$11.2 billion in FY2011

- Focused on three primary areas of importance:
  1. Increasing research investment
  2. Strengthening educational opportunities in science, technology, engineering, and mathematics from elementary through graduate school
  3. Developing an innovation infrastructure

NSB Report (2009): Building a Sustainable Energy Future



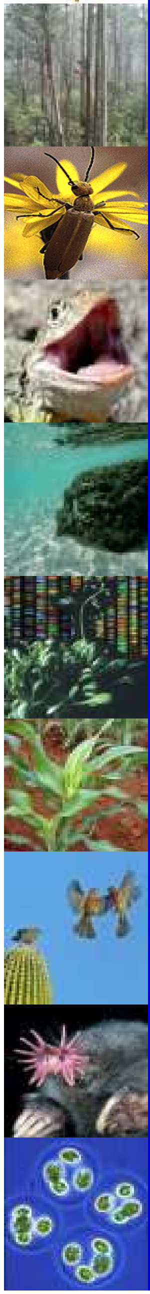
Priority Guidance: NSF should continue to increase emphasis on innovation in sustainable energy technologies and education as a top priority.

NSB offers the following specific guidance to NSF:
“Strengthen systems approaches in research programs.”

“Develop and strengthen interdisciplinary systems approaches for research programs”

National Research Council of the National Academies of Sciences

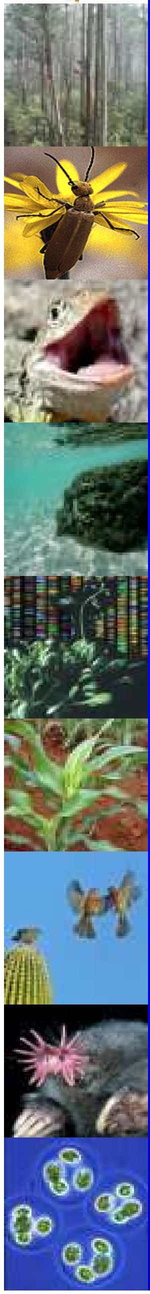
Released 2009



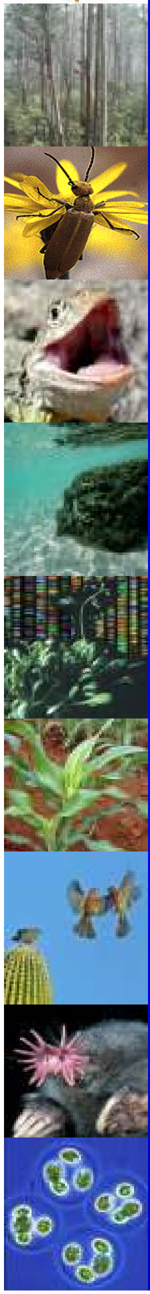
NRC Recommendations for Restructuring Federal Climate Research

- Integrated scientific-societal issues
- Interactions among the climate, human, and environmental systems
- U.S. climate observing system including physical, biological, and social observations
- Coupled Earth system models
- Adaptation

Shortly before the last BIO-AC meeting



Source: http://www.whitehouse.gov/blog/09/04/27/The-Necessity-of-Science/



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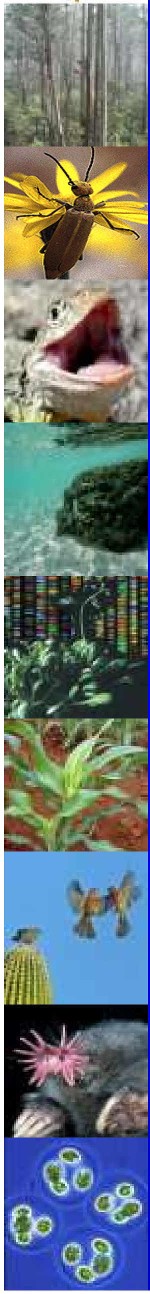


American Recovery & Reinvestment Act

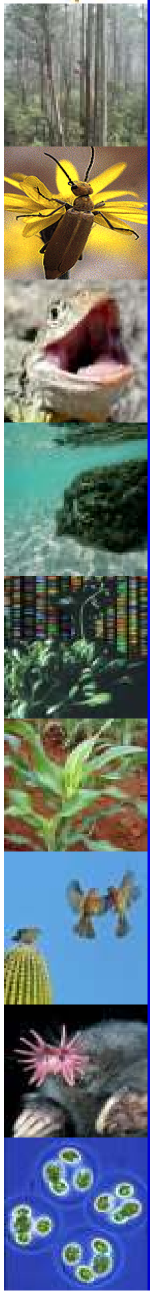
Supplemented FY 2009 funding by $3B

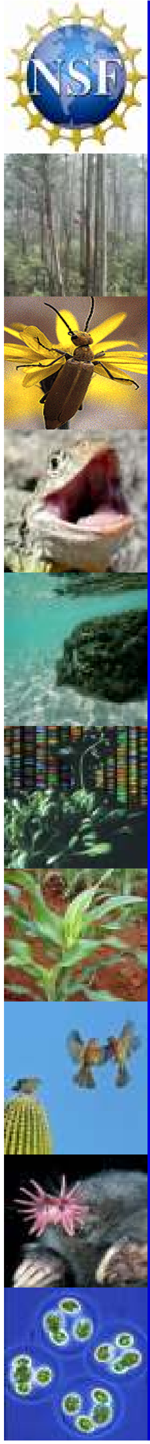
- **$2B for Research and Related Activities (R&RA):**
  - **NSF used most of the funds for proposals that were already in house and were reviewed and/or awarded prior to September 30, 2009**
- **$1B specified for:**
  - **Math and Science Partnership Program ($25 M)**
  - **Robert Noyce Teacher Scholarship Program ($60 M)**
  - **Science Masters Program ($15 M)**
  - **Academic Research Infrastructure Program ($200 M)**
  - **Major Research Instrumentation Program ($300 M)**
  - **Major Research Equipment & Facilities Construction ($400 M)**

American Recovery & Reinvestment Act

BIO Investments ($260M)

- ~98+% into core programs
- Supported FY 2009 awards thereby freeing up resources to pay down FY 2010 mortgage creating “investment space” in FY 2010



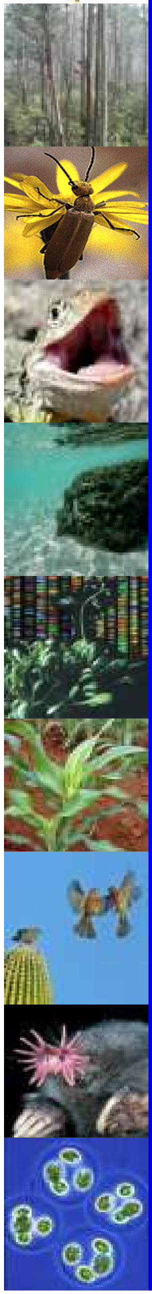


American Recovery & Reinvestment Act

BIO Investments ($260M)

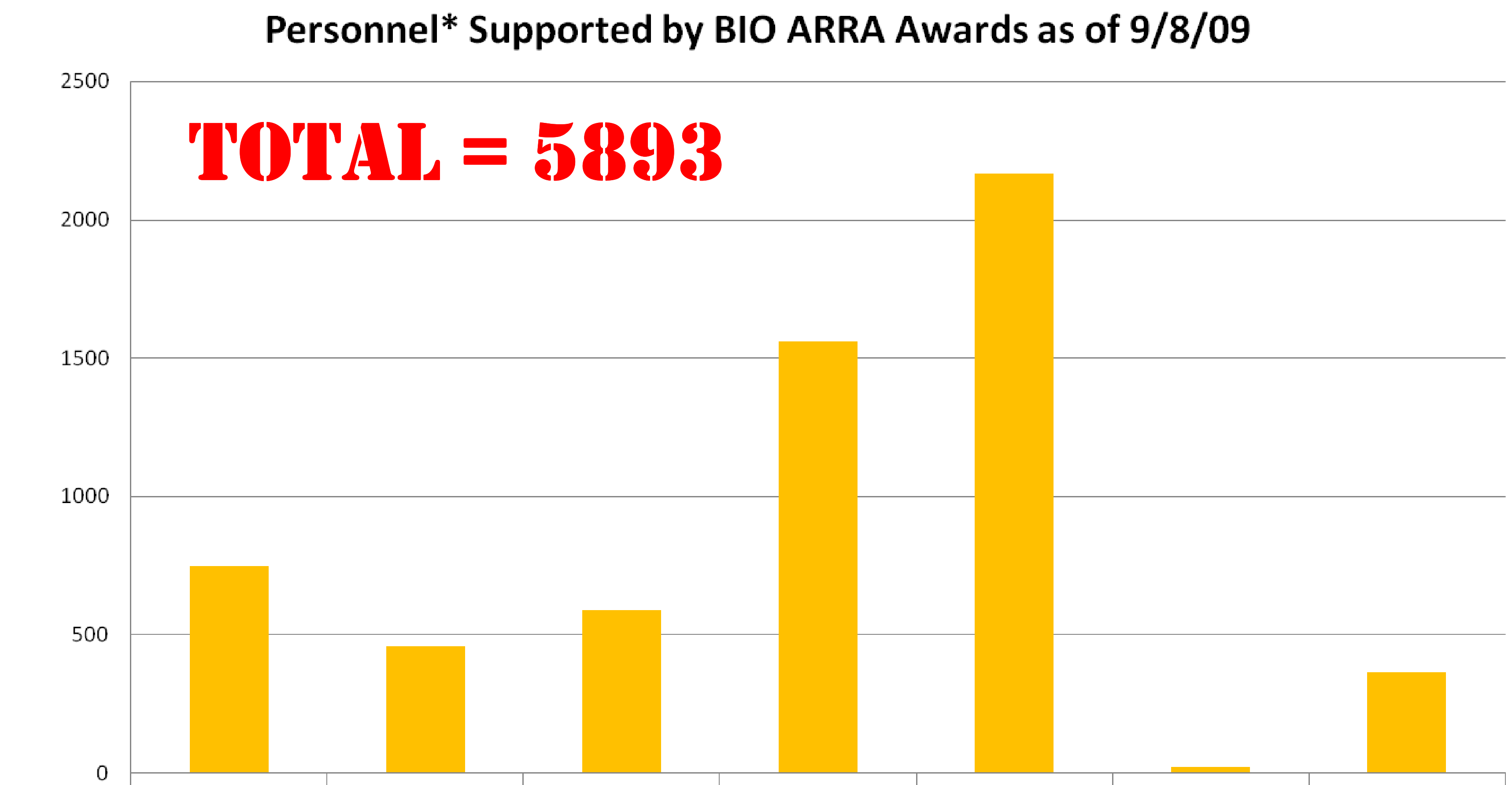
- Doubled number of CAREER awards
- Seeded Dimensions of Biodiversity activity
- Digitization of Natural History Collections
- Funded NEON Airborne Observatory Platform prototype
- Enhance cyberinfrastructure of LTER Network

BIO ARRA Portfolio - $260M



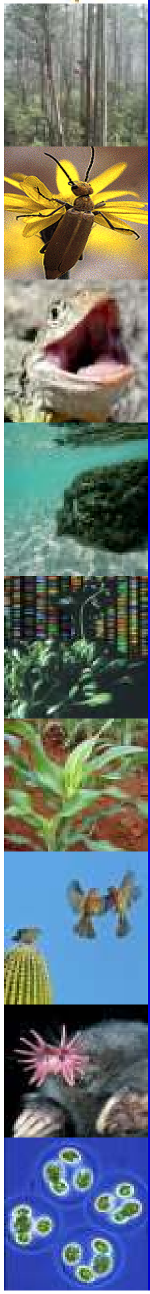
- 555 awards across 47 states, District of Columbia, Puerto Rico, and the Virgin Islands.
- Average award was $455,769 and 3.21 years
- 57 high risk awards
- 39 awards targeting energy
- 126 climate change focused awards
- 55 CAREER awards
- 168 new PIs
- 157 beginning investigators

ARRA & Biological Sciences Jobs



	Senior Researchers	Other Professionals	Postdoc	Grad Student	Undergrad Student	Secretary-Clerical	Other Personnel
Personnel	745	455	587	1558	2166	19	363

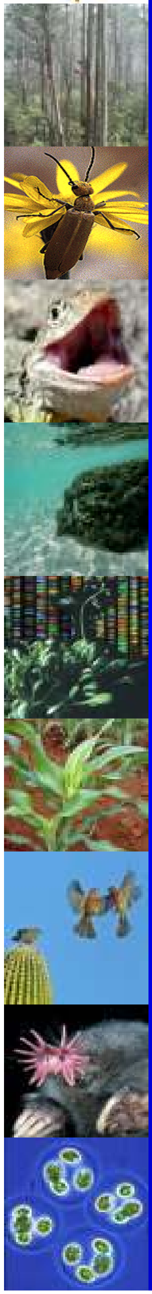
*Note this is not equivalent to the jobs created information that will be reported by recipients. PIs are required to report full-time equivalent (FTE) whereas NSF captures headcount statistics from the award (as submitted in the proposal). http://www.nsf.gov/recovery/



“This award is funded under the American Recovery and Reinvestment Act of 2009 (Public Law 111-5).”

- Since 1 October 2008, BIO has made 1867 awards totaling $621M so far.
- Since Memorial Day BIO has made 1432 awards totaling $539M.
- Of those, 560 were ARRA awards totaling $265.6M.

*All numbers current as of 9/9/09.



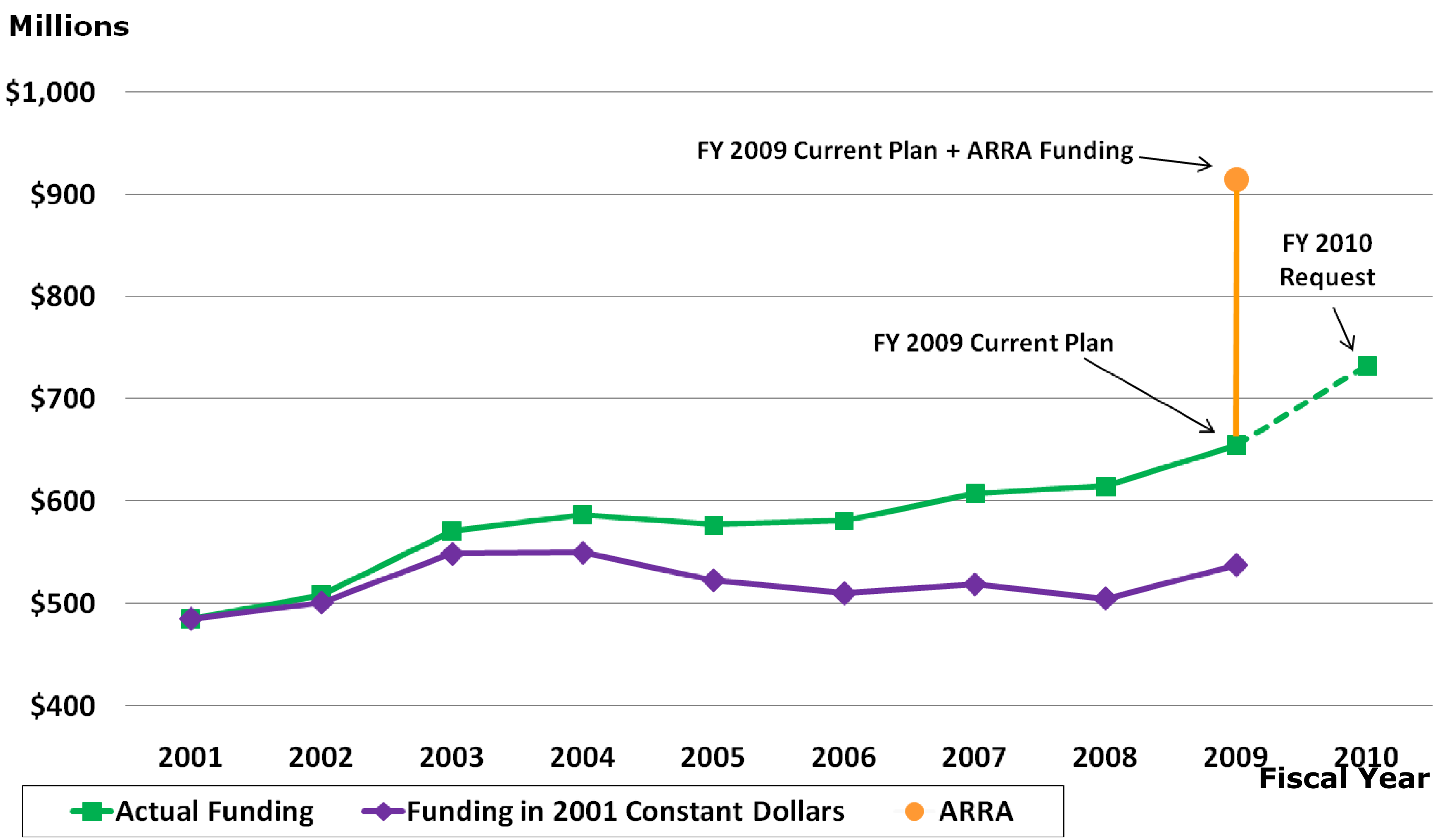
A BIO Summer Story: 1432* awards totaling $539M since Memorial Day

That's an average of $7.2M (19.1 awards) per day BIO staff sent out the door into the hands of the biological sciences community every single business day of summer.

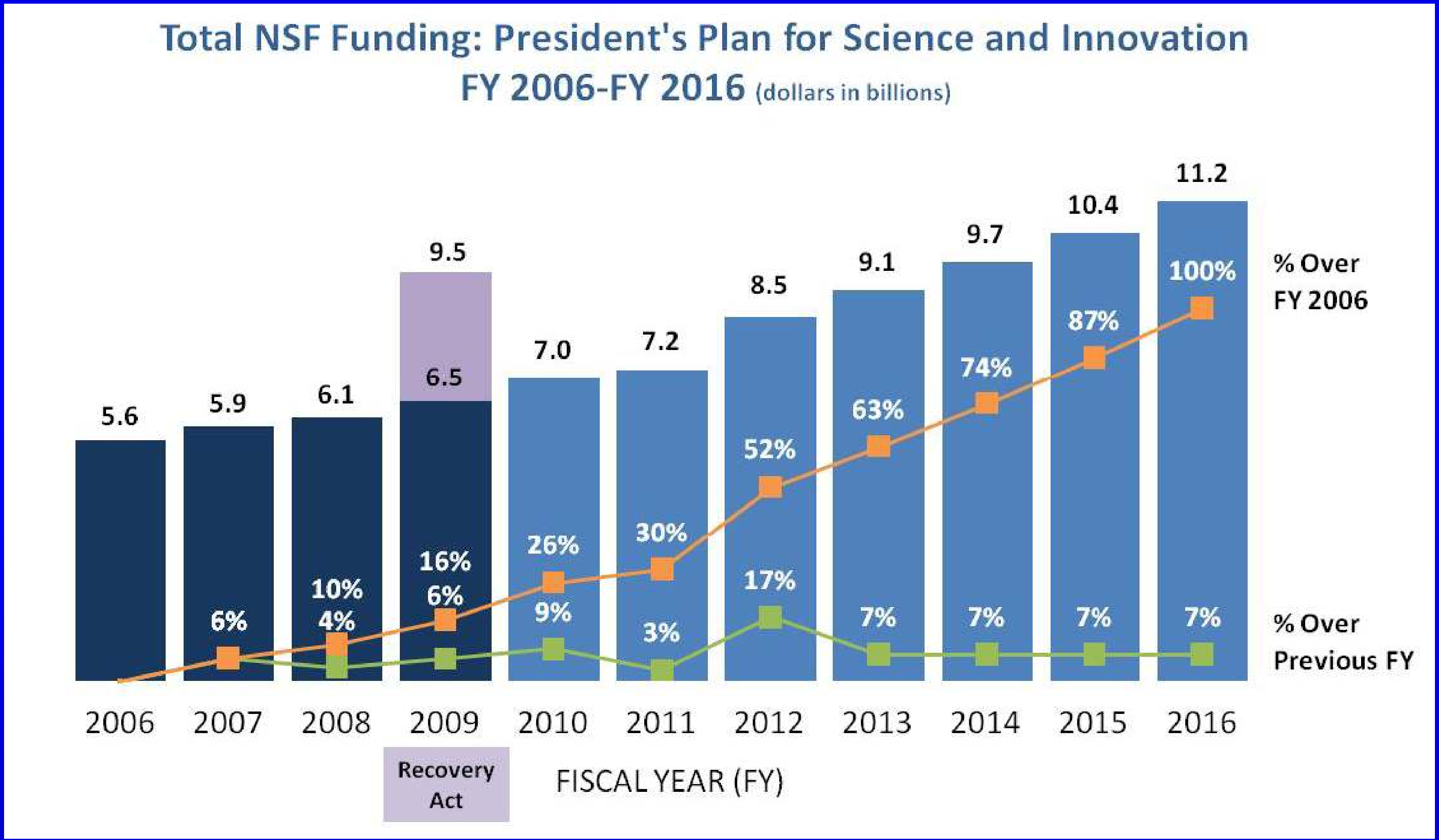
- **And the money is being used right now. For example, $8.5M of ARRA money supported an additional 35 biological sciences REU sites this year putting science students to work in their field of study.**

***All numbers current as of 9/9/09. Unless specified, number includes ARRA + FY 2009 funds.**

Recent Funding History of BIO Directorate FY 2001-2009

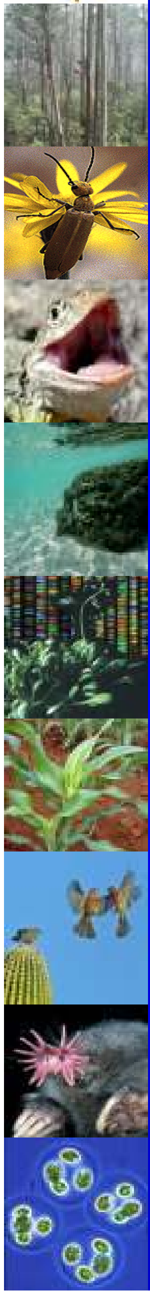


FY 2010 Budget Request to Congress



Source: NSF FY2010 Budget Request to Congress

NSF Requests $7B for FY 2010



- Improve American competitiveness
- Support early career researchers
- Educate science and engineering technicians
- Encourage promising high-risk research
- Prioritize climate change research and education

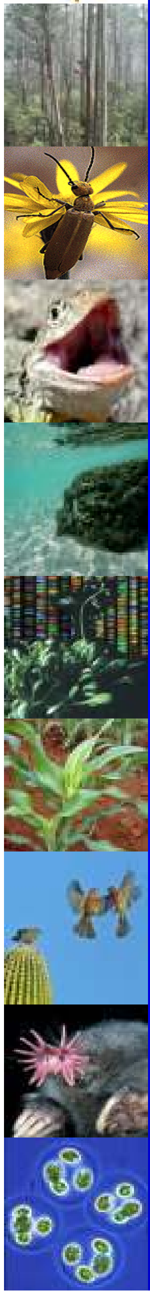
http://www.nsf.gov/about/budget/fy2010/toc.jsp

FY2010 Budget Request for Research & Related Activities by Directorate

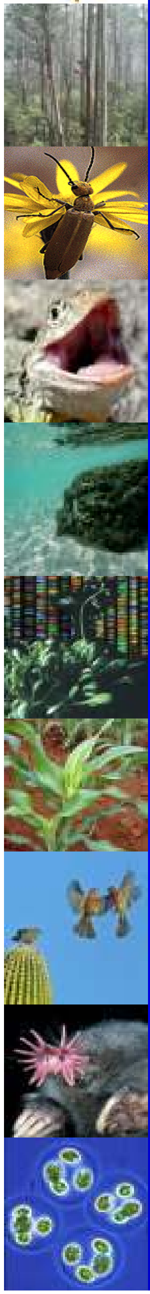
Research and Related Activities Funding						
(Dollars in Millions) (Totals may not add due to rounding)	FY 2008 Actual	FY2009 Current Plan	FY 2009 ARRA Estimate	FY 2010 Request	Change over 2009 Plan	
FY 2010 R&RA Request by Directorate					$	%
Biological Sciences[1]	$615.62	$655.81	260.00	$733.00	$77.19	11.8%
Computer & Information Science & Engineering[1]	535.26	573.74	235.00	633.00	59.26	10.3%
Engineering[1]	649.49	693.34	265.00	764.52	71.18	10.3%
Geosciences	757.87	807.13	347.00	909.00	101.87	12.6%
Mathematical & Physical Sciences	1,171.13	1,255.96	490.00	1,380.00	124.04	9.9%
Social, Behavioral & Economic Sciences[1]	227.87	240.30	85.00	257.00	16.70	6.9%
Office of Cyberinfrastructure	185.15	199.28	80.00	219.00	19.72	9.9%
Office of International Science & Engineering[2]	47.77	44.03	14.00	49.00	4.97	11.3%
Office of Polar Programs	447.13	470.67	174.00	516.00	45.33	9.6%
Integrative Activities	214.48	241.34	550.00	271.12	29.78	12.3%
U.S. Arctic Research Commission	1.47	1.50	-	1.60	0.10	6.7%
Total, Research & Related Activities	$4,853.24	$5,183.10	$2,500.00	$5,733.24	$550.14	10.6%

Source: NSF FY2010 Budget Request to Congress

FY 2010 BIO Priorities



1. Climate Research ($46M)
2. Innovation (+$20M)
3. Disciplinary Research: Enhancing the Core (+$38M)
4. Research Resources (+$20M)
5. National Ecological Observatory Network (+$200K)
6. Education & Learning (+$11.5M)



1. Climate Research ($46M)

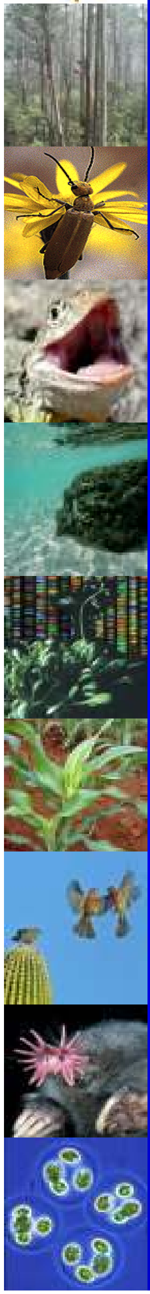
- Modeling , scaling, complexity
- Fundamental research
- Environmental observation
- Adaptation

Climate Change

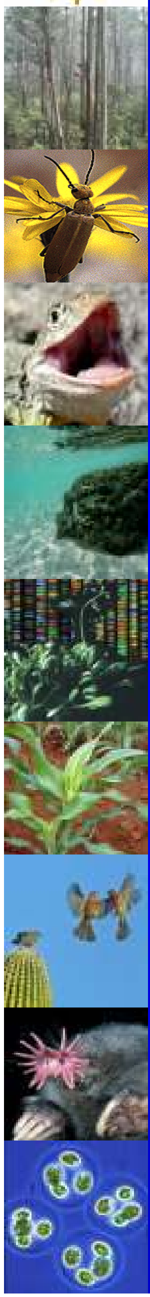
"All requested increases for climate change in the various research programs are supported."

House Report 2847. Commerce, Justice, Science, and Related Agencies Appropriations Bill, 2010. June 12, 2009

2. Innovation (+$20M)



- Interdisciplinary research
- Collaborative processes
- Process of discovery



3. Disciplinary Research: Enhancing the Core (+$38M)

- BIO investments support integrative fundamental research across the biological scales, from intracellular macromolecules to the biosphere and results in the discoveries and new knowledge needed to address issues of national importance.

Terrestrial Ecosystems Research

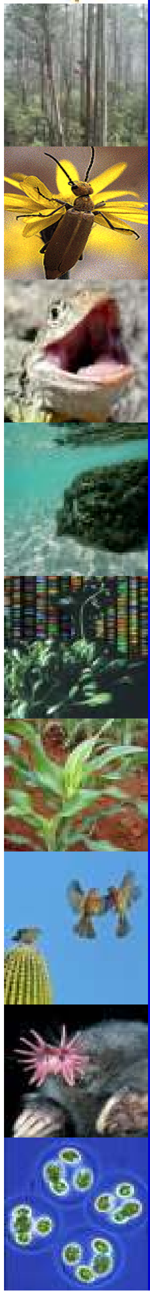
“The Committee also sees the need for an appropriate mechanism to bring together the terrestrial ecology research community including the existing Long Term Ecological Research sites and their data … and the new NEON distributed observing system. NSF is directed to report its recommendations on the need for and establishment of mechanisms … with the budget request for fiscal year 2011.”

H.R. 2847

Metagenomics Research

"In environmental research and soil science, the new approach of metagenomics, in which genes are identified within samples without isolating individual species, is of increasing value."

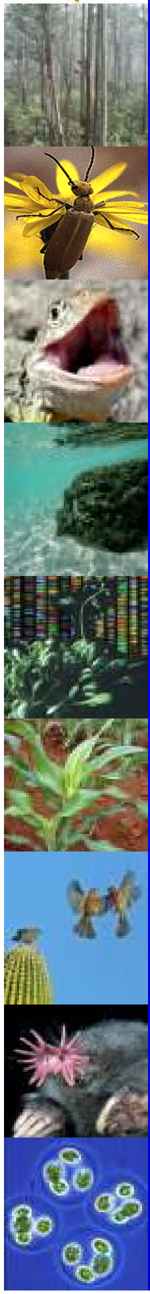
H.R. 2847



4. Research Resources (+$20M)

- Scientific collections
  - Continue efforts to digitize & network U.S. specimen-based research collections
- Enhanced support for research resources
  - Advances in Biological Informatics (ABI)
  - Instrument Development for Biological Research (IDBR)

5. National Ecological Observatory Network (NEON) (+$200K)

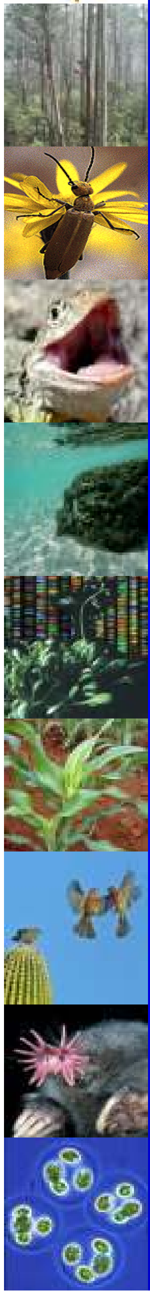


- Increased investment in project planning
- Sustain project design and development activities
  - Preliminary design review completed in June 2009
  - Final design review scheduled for early FY 2010
- Confirmation of baseline estimates for construction will inform FY 2011 budget request

Distributed and Networked Observing Systems

"Future major research equipment projects that involve spatially distributed networks of sensors, such as envisioned for NEON, are likely to be critical resources required for use by many researchers in oceanography, limnology, terrestrial and marine ecology and other fields. Funding for such systems is appropriate for inclusion in MREFC."

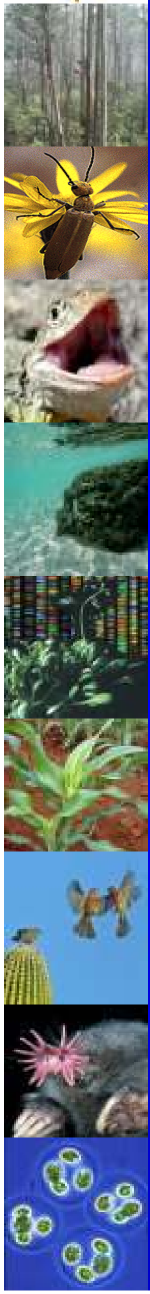
H.R. 2847



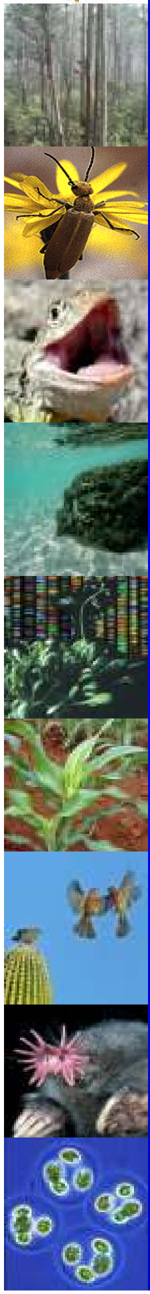
New Tools and Approaches

National Ecological Observatory Network (NEON)

NEON Data & Data Products



- Data Generated TB/Yr
- Sensors (~18,000)
- Raw 75
- Processed 12
- Sentinel 1
- Remote Sensing 124
- Total 212



nature

www.nature.com/nature

Vol 460 | Issue no. 7255 | 30 July 2009

Information overload

A report released last week by the US National Academies makes recommendations for tackling the issues surrounding the era of petabyte science.

Geneticists spent more than a decade getting their first complete reading of the 3 billion base pairs of the human genome, which they finally published in 2003. But today's rapid sequencing machines can run through that much DNA in a week, and are busily churning out multiple sequences from an ever-expanding list of species. Meanwhile, astronomers working with the Sloan Digital Sky Survey telescope in New Mexico have mapped some 25% of the sky since 2000, obtaining data on more than 200 million objects. The Large Synoptic Survey Telescope, scheduled for completion atop Chile's Cerro Pachón in 2015, will gather that much data in one night.

Statistics tell a similar story in many scientific fields. This is great news for research: data glut is always better than data famine. But it

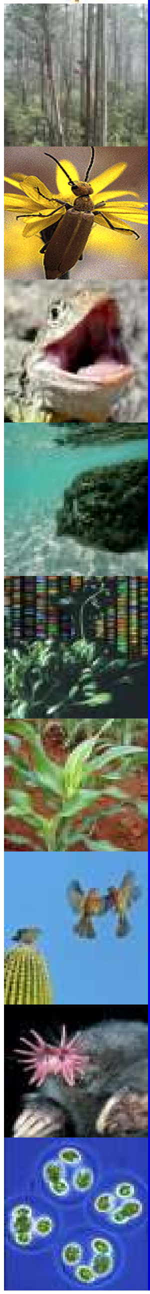
their fields, and institutions should ensure that training is in place to make this possible.

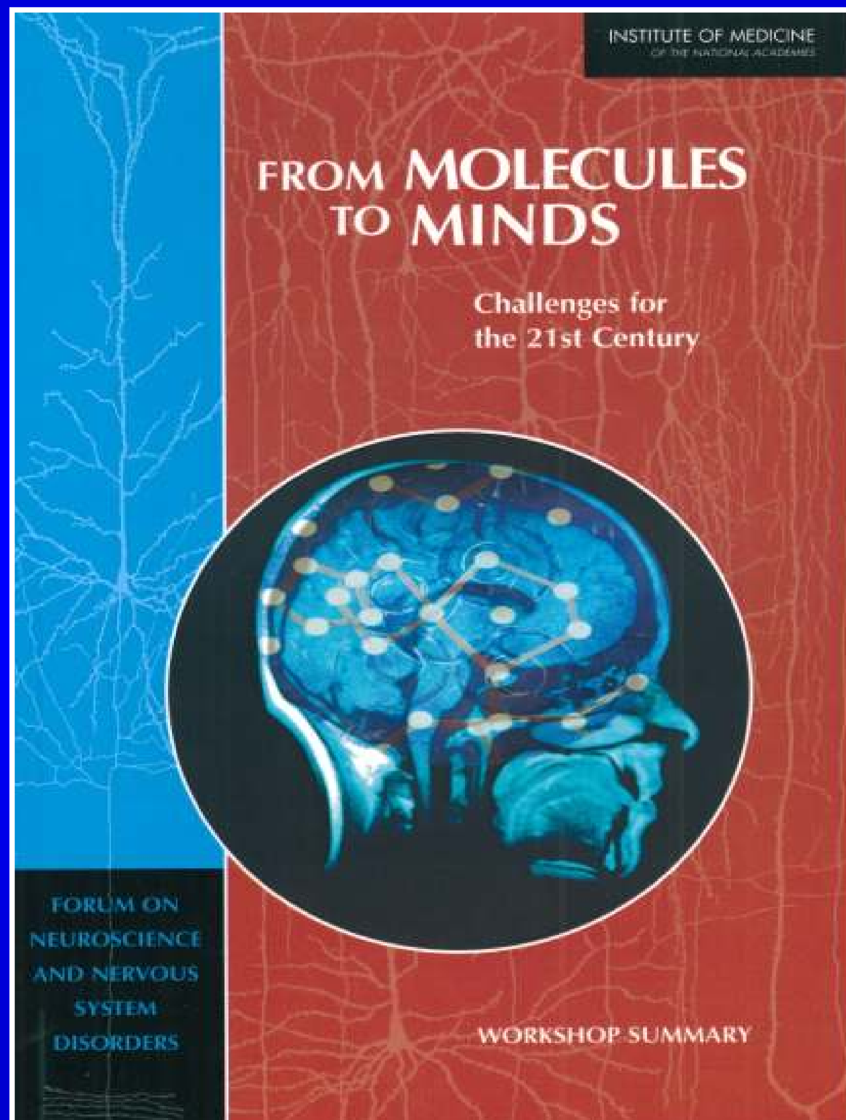
The access principle asserts the value of openness: only if results are shared can other researchers check the data's accuracy, verify analyses and build on previous work. So unless there are very good reasons for researchers to withhold data — reasons that should be publicly posted and available for comment by other researchers — they should make provisions to supply public access in a timely manner, possibly as early as their grant proposals.

Finally, the stewardship principle addresses the need for long-term pres-

"Each researcher is ultimately responsible for ensuring the

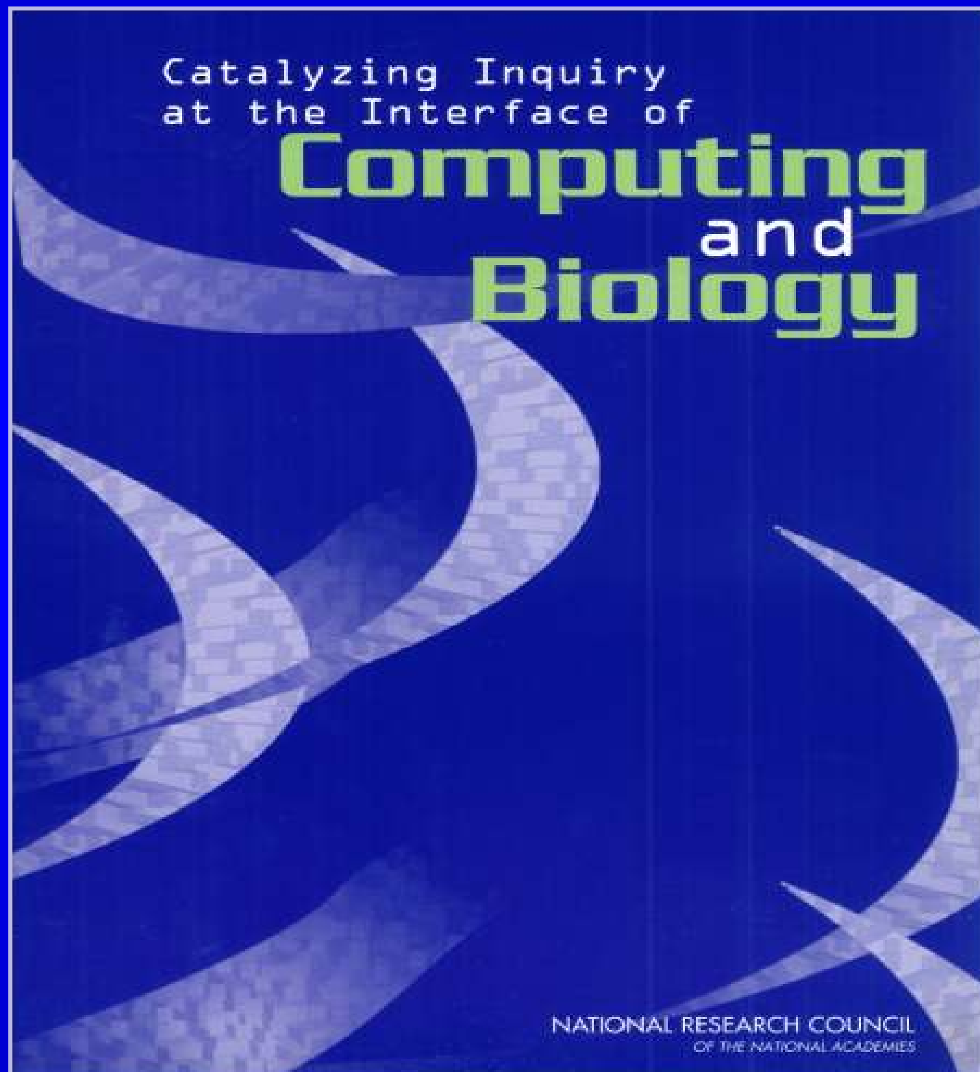
Multiscale-Thinking





2008

Computational Thinking



2005

EDUCATION

Computing Has Changed Biology—Biology Education Must Catch Up

Biologists need better computational education so that researchers can benefit from the bioinformatics revolution.

Pavel Pevzner[1]* and Ron Shamir[2]

Advances in computing have forever changed the practice of biological research. Computational biology, or bioinformatics, is as essential for biology in this century as molecular biology was in the last. In fact, it is difficult to imagine modern molecular biology without computational biology. For example, a difficult algorithmic puzzle had to be solved in order to successfully assemble the human genome sequence from millions of short pieces.

However, the computational components of undergraduate biology education have hardly changed in the past 50 years. New courses for biologists should be more relevant to their discipline, complementing the standard mathematical courses that were and mathematicians from various branches of bioinformatics agreed that the time has come to shift the paradigm in biology education by adding new computational courses to standard curricula. This realization is not new: *BIO2010*, a National Research Council report (*1*), recommended substantial changes in the mathematics curricula for research-oriented biology undergraduates. Bialek and Botstein (*2*) and Pevzner (*3*) acknowledged the problem and outlined some creative approaches to its solution. However, the question of how best to deliver computational ideas to biologists remains.

Because bioinformatics is a computational science, courses should strive to present the ideas that drive an algorithm's design and computational ideas and ensures that they are able to apply them?

Consider the problem of analyzing gene expression data by principal component analysis (PCA), a powerful computational technique used by thousands of biologists. PCA is not typically covered in mathematics courses taken by biologists, so many may use PCA without understanding how it works or even what it does. A biologist who "blindly" uses PCA or other bioinformatics tools may misapply the method, miss important observations, misinterpret the results, and derive erroneous biological conclusions [see (*4*) for examples of misinterpretations of BLAST results].

Thus, we believe that undergraduate cur-

SCIENCE VOL 325 31 JULY 2009

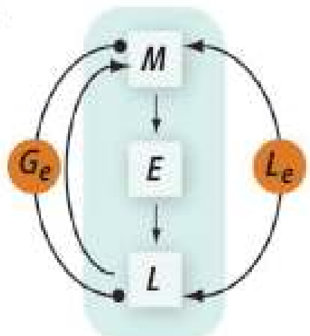
EDUCATION

Mathematical Biology Education: Beyond Calculus

Training in developing algebraic models is often overlooked but can be valuable to biologists and mathematicians.

Raina Robeva[1*] and Reinhard Laubenbacher[2]

In 2003, the National Research Council's *BIO2010* report recommended aggressive curriculum restructuring to educate the "quantitative biologists" of the future (*1*). The number of undergraduate and graduate programs in mathematical and computational biology has since increased, and some institutions have added courses in mathematical biology related to biomedical research (*2*, *3*). The National Science Foundation (NSF) and the National



$$\dot{M} = Dk_M P_D(G_e)P_R(A) - \gamma_M M \qquad f_M = \neg G_e \wedge (L \vee L_e)$$

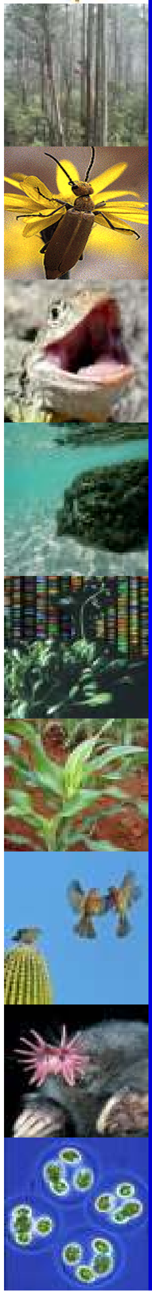
$$\dot{E} = k_E M - \gamma_E E \qquad f_E = M$$

$$\dot{L} = k_L \beta_L(L_e)\beta_G(G_e)Q - 2\phi_M \mathcal{M}(L)B - \gamma_L L \qquad f_L = \neg G_e \wedge E \wedge L_e$$

DE and Boolean models of the *lac operon* mechanism. Each component of the shaded part of the wiring diagram is a variable in the model, and the compartments outside of the shaded region are parameters. Directed links represent influences between the variables: A positive influence is indicated by an arrow; a negative influence is depicted by a circle.

SCIENCE VOL 325 31 JULY 2009

6. Education & Learning (+$11.5M)

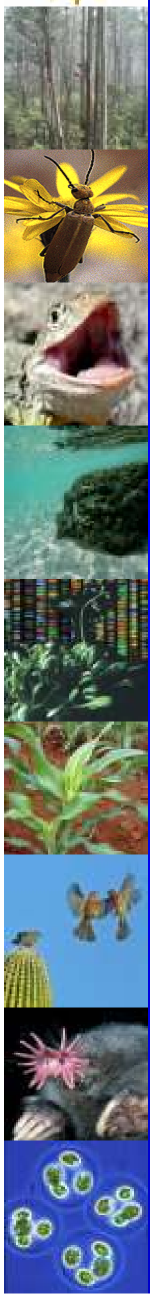


- Climate science partnerships with EHR, GEO, & OPP
  - Innovative formal and informal education activities
- BIO/EHR partnership activities:
  - Vision & Change in Undergraduate Biology Education Conference (July 2009) with AAAS
    - Proposed incubation grants to build upon themes
  - Research Coordination Networks (RCNs)
    - Join biology and education researchers with practitioners

Undergraduate Education

"…to support creation, adaptation, and dissemination of learning materials and teaching strategies that implement inquiry-based instruction in teaching science to future K-12 teachers and other undergraduates …"

H.R. 2847

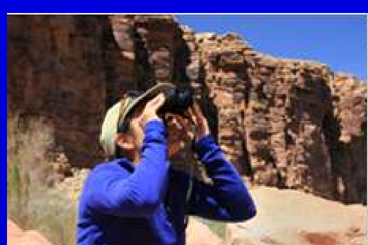


Life Sciences in Transition

Challenge: Catalyzing Community Change in Biology Education

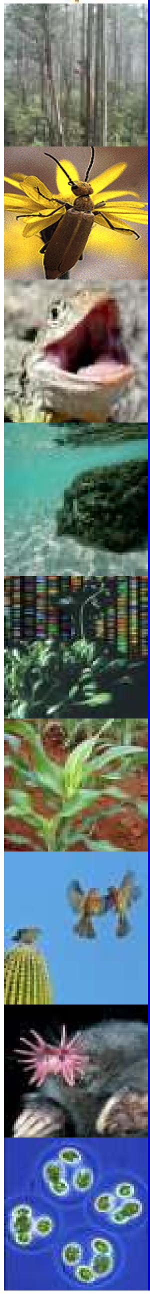
Prepare a new generation of scientists to communicate science as a precise, predictive, and reliable way of knowing the world.

Transforming Undergraduate Education in Biology: Mobilizing the Community for Change Conference (July 2009)



Vision & Change in Undergraduate Biology Education

A VIEW FOR THE 21st CENTURY



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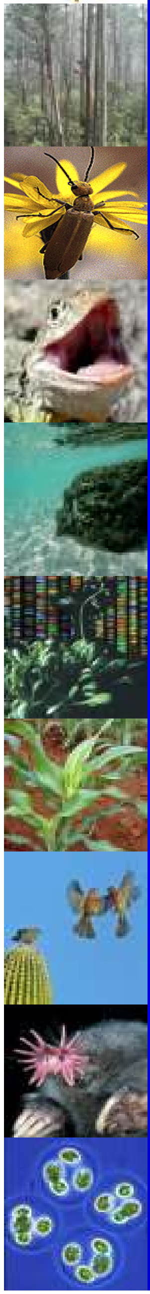
High-Risk, High-Reward Basic Research

"…set aside a minimum of $2,000,000 in each research division to explore methodologies that support transformative research."

H.R. 2847

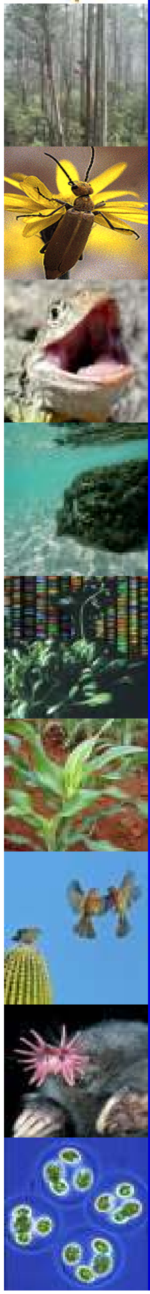


The Innovator's Dilemma

"Incumbents very seldom invent the future."

Eric Schmidt, CEO, Google

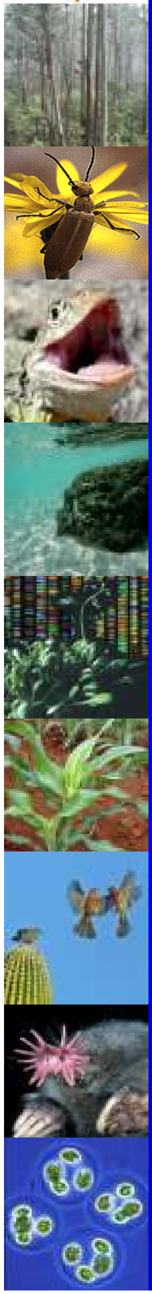
New York Times, April 15, 2009



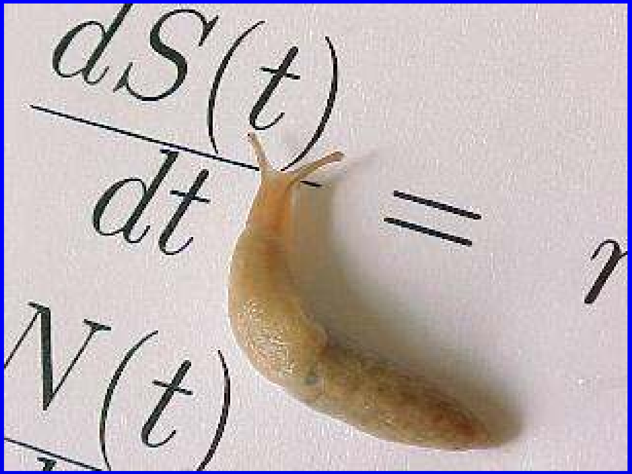
Experiments in Innovation

- **Stimulating multidisciplinary activities**
- **Building on existing links and exploring new partnerships across Divisions, Directorates, Agencies, NGOs, and international organizations, e.g.:**
  - **Integrated Global Systems Science (IGSS)**
  - **Coupled Natural and Human Systems (CNH)**
  - **Ecology of Infectious Diseases (EID)**
  - **Basic Research to Enable Agricultural Development (BREAD)**

Multidisciplinary Programs



Dynamics of Coupled Natural and Human Systems [BIO, GEO, SBE, & USFS]



Interdisciplinary Training for Undergraduates in Biological and Mathematical Sciences [BIO, EHR, & MPS]

Ecology of Infectious Diseases [BIO, GEO, SBE, & NIH]

Reaching Beyond Traditional Disciplines

Connections at the intersection of the life and physical sciences

NATURE CHEMICAL BIOLOGY, Sept 2008

COMMENTARY

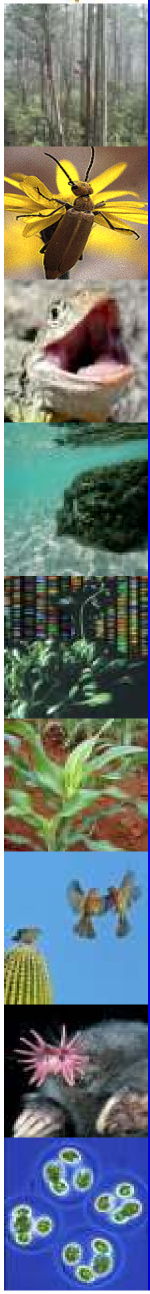
Chemical biology at the US National Science Foundation

Wilfredo Colon, Parag Chitnis, James P Collins, Janice Hicks, Tony Chan & Joanne S Tornow

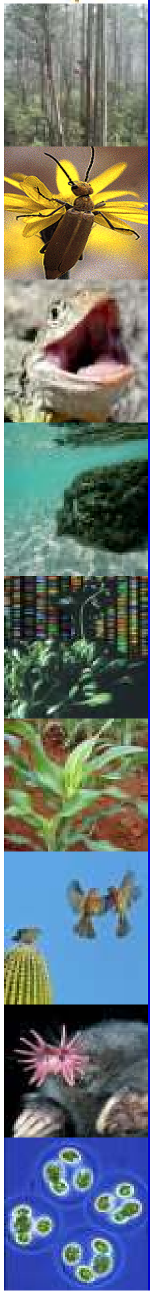
Chemical biology continues to grow and blur the theoretical and empirical boundaries between chemistry and biology. Federal funding agencies, including the US National Science Foundation, will be essential to support the development of interdisciplinary research fields.

*"In response to the growing number of proposals at the chemistry-biology interface…**CHE and MCB created a shared program director position…"***

Fostering Interdisciplinary Research



- **Encouraging interdisciplinary proposals through venture funds and Dear Colleague Letters**
- **Establish cross directorate working groups such as climate change education**
- **Exploring new models of program management**
  - *e.g., Integrated Global System Science - BIO and GEO*
- **Envisioning a more adaptable NSF structure**

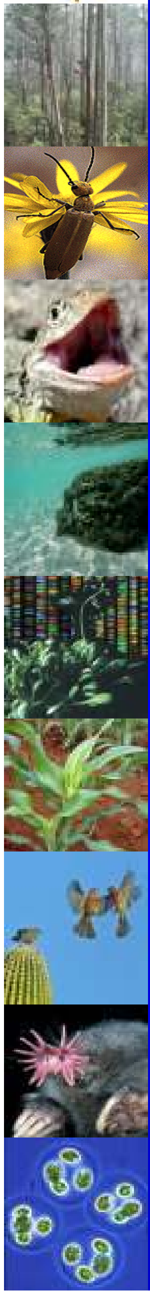


Reaching Beyond Traditional Disciplines

Integrated Global System Science (IGSS)

- **BIO & GEO are stimulating conversations** about Global Systems Science to move forward in support of the best interdisciplinary research ideas to equip society with the knowledge needed to address the challenges we face
- **Co-location of BIO and GEO personnel**
- **Distinguished Speaker Series**
- **Cross-Directorate Dear Colleague Letters** e.g., joint BIO-GEO activity in environmental modeling

Joint BIO-GEO activity in Biogeochemical Cycles



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Dear Colleague Letter: Update: Emerging Topics in Biogeochemical Cycles (ETBC)

February, 2009

Directorate for Geosciences and Directorate for Biological Sciences
NSF 09-030
(Replaces NSF 07-049)

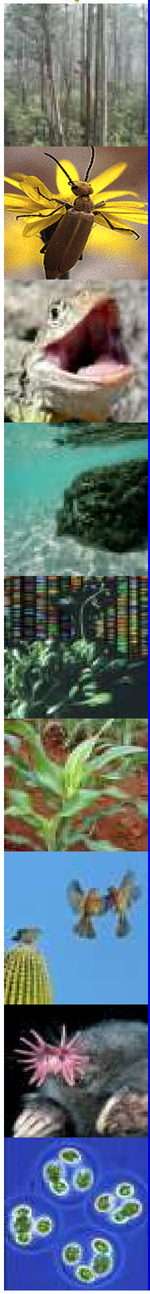
Dear Colleague:

The Directorate for Geosciences (GEO) and the Directorate for Biological Sciences (BIO) are enhancing support for interdisciplinary research which bridges across the biological, atmospheric, geological, oceanographic and hydrological sciences, in the area of biogeochemical cycles and processes.

We seek to support research that will advance our quantitative and/or mechanistic understanding of **biogeochemical cycles, including the water cycle.** Competitive proposals should integrate physical, geological, chemical, and/or hydrologic processes with biological processes over various temporal and/or spatial scales and/or various levels of biological organization. Proposals should be interdisciplinary and address biogeochemical processes and dynamics within and/or across one or more of the following systems: terrestrial, aquatic, and/or atmospheric. We encourage proposals that focus on nonlinear dynamics and/or on interactions and thresholds in climate, ecological, and/or hydrological systems. Goals of this effort are to increase our understanding of how biological systems respond to changing physical and chemical conditions and how biological systems influence the physical and chemical characteristics of soils and sediments, air, or water.

These types of emerging and challenging problems require integration of concepts and observations across diverse fields. A goal of the Biological Sciences and Geosciences Directorates is to enhance such integration. Successful proposals will generate intellectual excitement in all participating disciplinary communities. Also encouraged are proposals that have

Joint BIO-GEO activity in Multi-scale Modeling



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Dear Colleague Letter: Multi-scale Modeling (MSM)

February, 2009

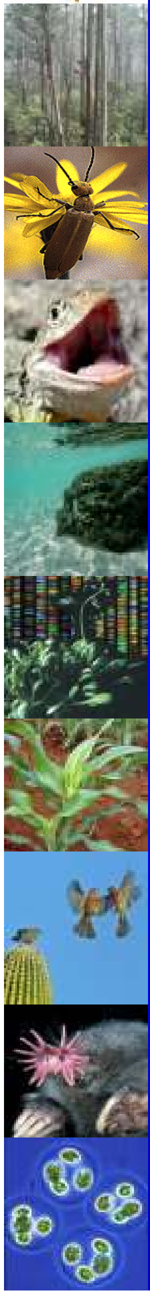
Directorate for Geosciences and Directorate for Biological Sciences
NSF 09-032

Dear Colleague:

The Directorate for Geosciences (GEO) and the Directorate for Biological Sciences (BIO) are enhancing support for interdisciplinary research which bridges from the biological to the earth system sciences in the area of multi-scale modeling.

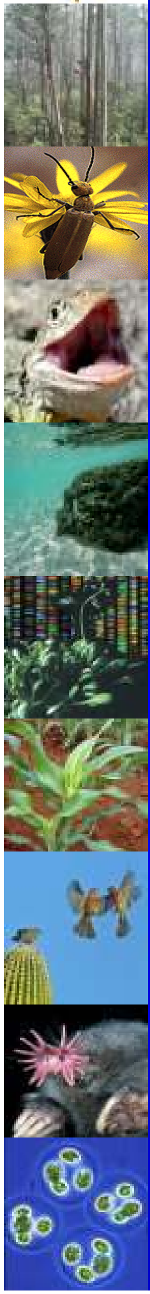
We seek to support projects that focus on the ***development and/or integration of environmental models that link local, regional and global scales***. Competitive projects should address key problems linking biological and Earth system processes over a variety of spatial and temporal scales. These projects will develop theoretical foundations for the modeling and simulations of existing data and data collected by the *new and envisioned NSF environmental observatories. [These include, for example, EarthScope, Critical Zone Observatories* (CZO), *the National Ecological Observatory Network (NEON), the Ocean Observatories Initiative (OOI), and many other projects and centers.]* Proposals are encouraged that *have the potential to dramatically improve our understanding of how* small and large scale processes lead to non-linearities and activation thresholds as well as to improve our predictive capabilities. Projects could address, but are not limited to, topics such as the carbon cycle, climate, population dynamics, foodwebs, biodiversity, biogeochemical cycles, and hydrological processes.

http://www.nsf.gov/pubs/2009/nsf09032/nsf09032.jsp?org=NSF



"In all affairs it's a healthy thing now and then to hang a question mark on the things you have long taken for granted."

Bertrand Russell



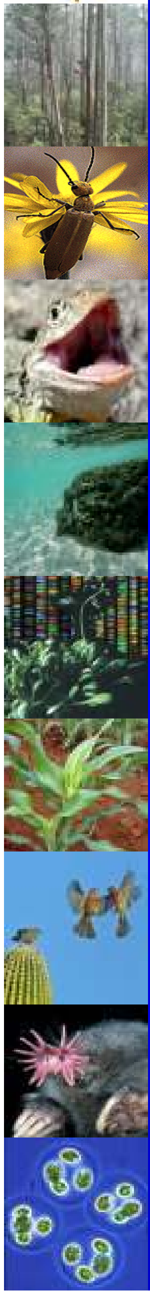
Process of Discovery

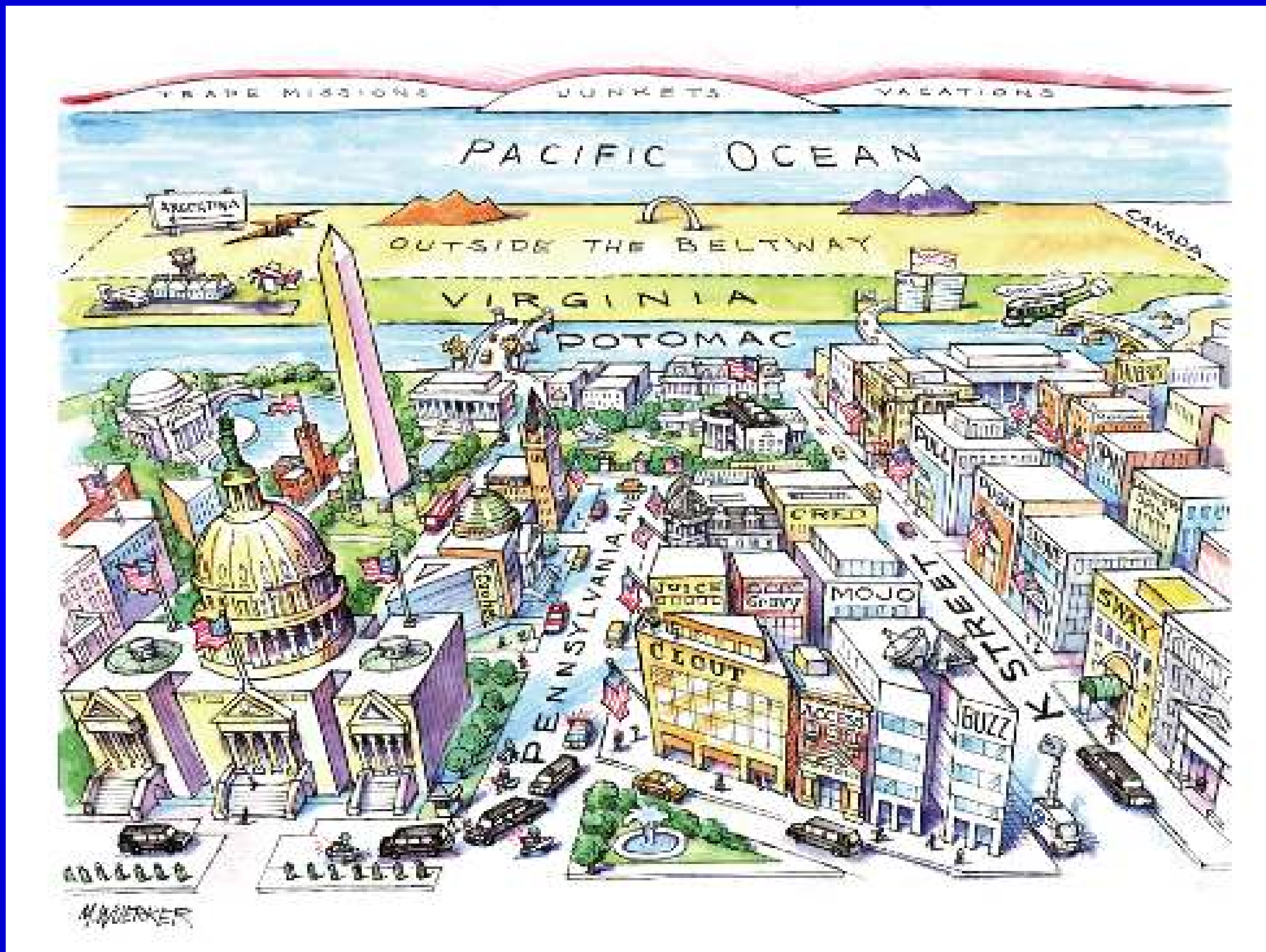
- Exploring novel processes for identifying frontier research:
  - Crowd sourcing
  - Clean slate
  - Sandpits
  - Creativity training for Program Directors
  - Synthesis centers
  - Prediction markets

Outline

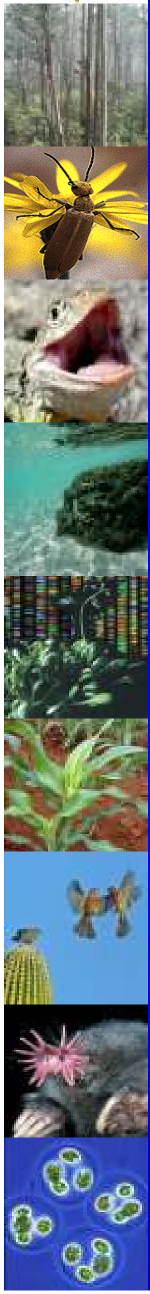
- The Changing Science and Technology Environment
- NSF Budget and Activities
- Fostering Innovation
- Promoting a Tipping Point in Academia

Catalyzing Community Change





Cover of *Politico*, July 11, 2009



Opportunity

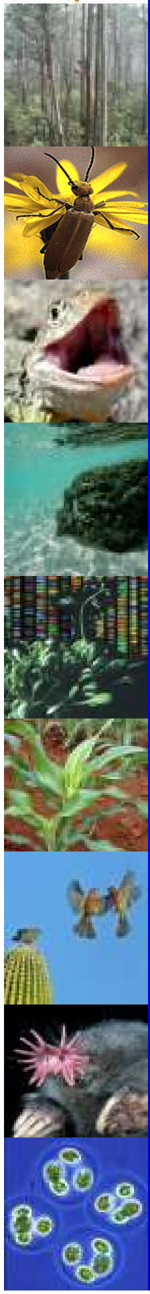
"This is how we will lead the world in new discoveries in this new century. But I think all of you understand it will take far more than the work of government. It will take all of us. It will take all of you. And so today I want to challenge you to use your love and knowledge of science to spark the same sense of wonder and excitement in a new generation."

President Barack Obama

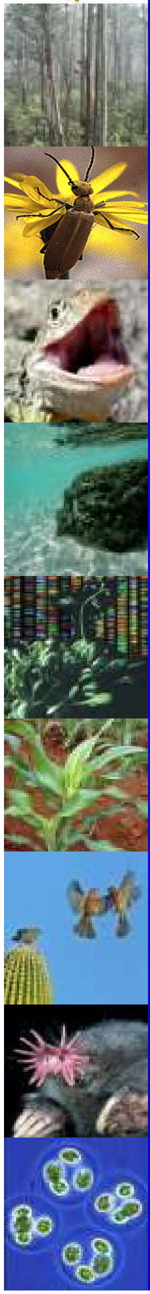
National Academy of Sciences 146th Annual Meeting

Washington DC, April 27, 2009

Guidance on FY 2011 Priorities



http://www.ostp.gov/galleries/press_release_files/Final%20Signed%20OMB-OSTP%20Memo%20-%20ST%20Priorities.pdf



Outline

- The Changing Science and Technology Environment
- NSF Budget and Activities
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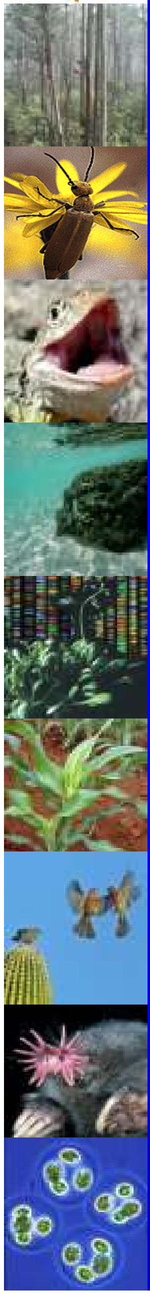
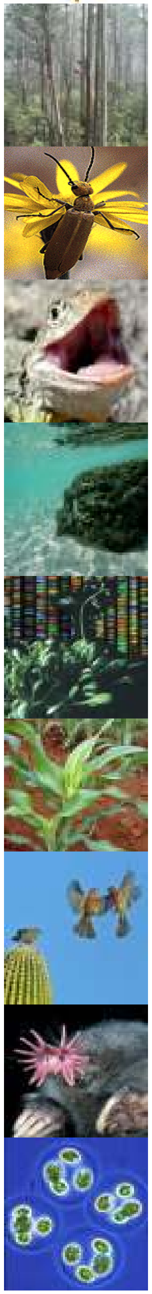


Innovating in the Midst of Excellence

"The goal is an organization that is constantly making its future rather than defending its past."

Hamel & Valiksngas, 2003



Where discoveries begin